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# Bread Water Content Measurement Based on Hyperspectral Imaging

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**Abstract.** Water content is one of the most important properties of the bread for tasting assesment or store monitoring. Traditional bread water content measurement methods mostly are processed manually, which is destructive and time consuming. This paper proposes an automated water content measurement for bread quality based on near-infrared hyperspectral imaging against the conventional manual loss-in-weight method. For this purpose, the hyperspectral components unmixing technology is used for measuring the water content quantitatively. And the definition on bread water content index is presented for this measurement. The proposed measurement scheme is relatively inexpensive to implement, easy to set up. The experimental results demonstrate the effectiveness.

**Keywords:** water content measurement, hyperspectral image, nonnegative matrix factorization

## 1 Introduction

The water content is one of the most important properties of the bread for tasting assesment or store monitoring. Generally, the higher the water content, the fresher the bread will be perceived by the consumers. On the other hand, too much water may be too soft for shaping. Therefore, evaluating the water content quantitatively is important for making bread.

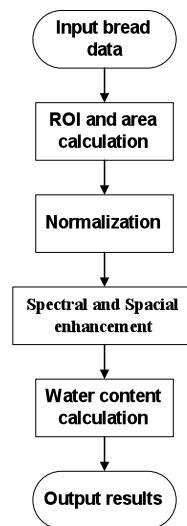
Traditional methods for measuring the water content of bread are mostly destructive and time consuming. Recently, some work based on spectroscopic analysis has been done on food inspection [1,2]. Sepctrum imaging is relatively new technology to the agriculture and food industry. In spectroscopic analysis, hyperspectral imaging takes the advantage of both spectroscopic and image processing techniques, which can be simultaneously analyzed to see the spatial variations in an image as well as variations in spectral response of the pixels in an image. Both spatial and spectral information is important for quality monitoring and visualization of the food product as it can be used to extract the chemical mapping of

the sample and to analyze the distribution of chemical components in a sample. So using hyperspectral image technology for bread quality assessment over the storage period is a promising approach, which is non-contact and non-distractive.

In this paper, the proposed method for measuring the water content of bread is based on near infrared (NIR) spectrum imaging, which includes hyperspectral image preprocessing, spectral signature unmixing [3], and water content calculation. The primary purpose of this paper is to measure the water content of bread against the conventional loss-in-weight method for rapid and accurate quality assessment.

## 2 The scheme for water content measurement

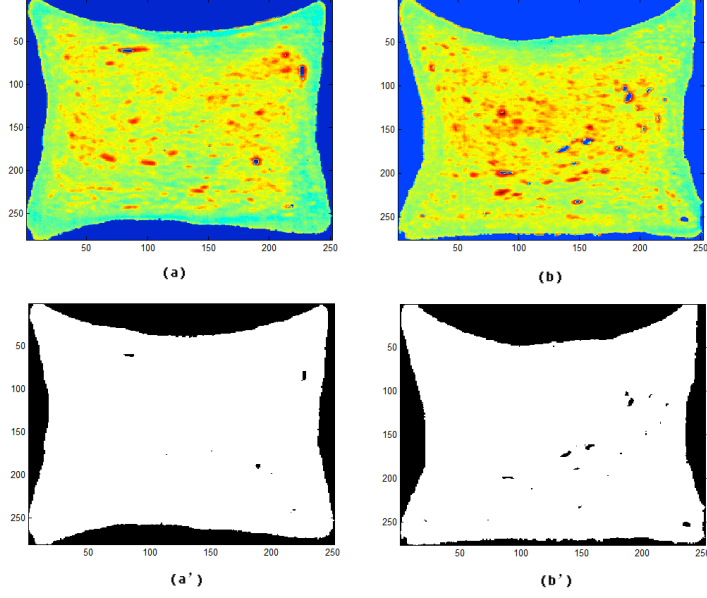
The scheme mainly includes preprocessing (selection of region of interest (ROI), normalization and smooth), unmixing and water content calculation, which are demonstrated in Fig.1.



**Fig. 1** the flowchart of the scheme for water content measurement

### 2.1 ROI

Spectroscopic systems should get more spatial field of view than the bread sample. Therefore hyperspectral imaging systems acquire abundant spatial information while collecting spectral information. So the selection of ROI can not only improve the accuracy of the measurement but also reduce the computing cost. In this study, the thin bread slice always has some holes which can affect the measurement significantly (shown in Fig 2).



**Fig. 2** The illustration of ROI operation

## 2.2 Normalization

Because of some sensory noise, the reflection spectral properties have some negative value. This problem is against the law of physics. Therefore, it is necessary to normalize the reflectance value. In this study, Eq. (1) is used for normalization.

$$w_{ijk} = \begin{cases} \frac{w_{ijk} - \arg(\min(w_{ijk}))}{\left\| \arg(\max(w_{ijk})) - \arg(\min(w_{ijk})) \right\|_2} \\ 0, & w_{ijk} < 0 \end{cases} \quad (1)$$

where  $w_{ijk}$  is the reflectance value at pixel the  $i^{th}$  row  $j^{th}$  column  $k^{th}$  waveband.

## 2.3 Spectral and spacial enhancement

Since reflectance at both small and large scattering distances is needed for accurate determination of the optical properties of the samples, an adequate signal-to-noise ratio (SNR) should be maintained, which is especially important for large scattering distances. For this reason, spectral averaging over three consecutive wavelengths was first performed to improve the SNR of the image data. Furthermore, the spatial

profiles from the two sides of the incident point were averaged to further enhance the SNR of the sample data.

## 2.4 Spectral unmixing

Non-negative Matrix Factorization (NMF) [4] is a matrix factorization algorithm that focuses on the analysis of data matrices whose elements are nonnegative, which can be used to extract the spectra of endmembers from the multi-array of mixed spectral observations.

## 2.5 Water content calculation

The conventional methods for the measurement of water content including drying the bread in an oven and weighting the bread slice are practicable, but they are also destruction and time consuming and difficult to integrate to on-line quality assessment. Therefore, the quantitative and non-contact methods for measuring the water content are necessary in bread production [5].

Considering the fact that the bread reflectance is predominantly affected by the optical properties of bread components, flour and water, the water content index (WCI) is proposed for measuring the water content.

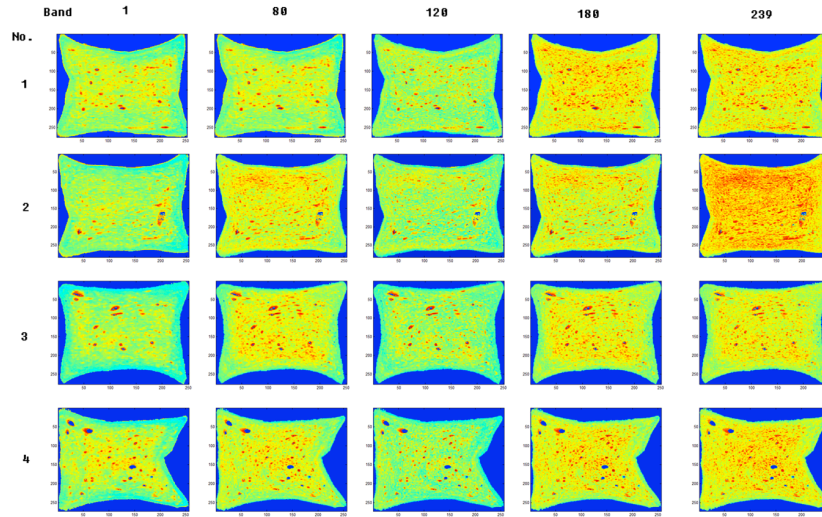
WCI is defined as Eq.(2).

$$W = \log\left(\frac{\sum a_{ij}}{A}\right) = \log\left(\frac{\sum \left\|\left(\frac{1}{v_{ij}} - \frac{1}{v_{ref}}\right)\right\|}{A}\right) \quad (2)$$

where  $a_{ij}$  notes the water abundance at each pixel, and the  $\left\|\left(\frac{1}{v_{ij}} - \frac{1}{v_{ref}}\right)\right\|$  represents the absolute value of the abundance value difference between the testing pixel and the reference value, and  $A$  means the area of the testing bread effective region, i.e. the ROI. So the index is higher, the level of water content in bread is higher.

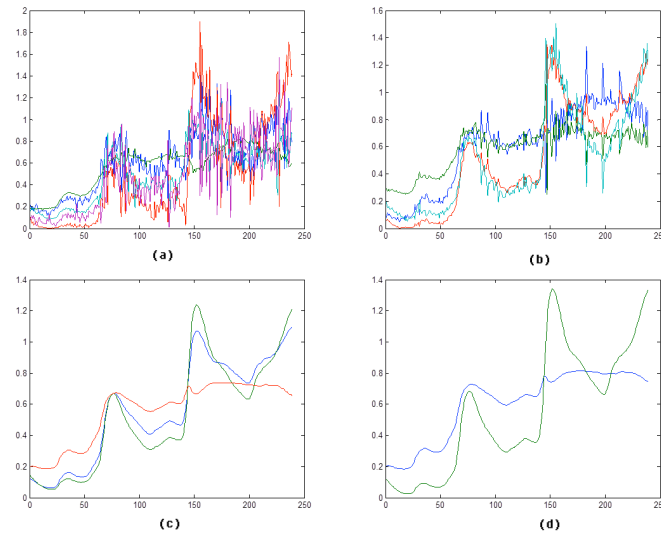
## 3 Experimental results

Some NIR bread images used for the experiments are shown in Fig.3. These images are from four different kinds of bread slices with the selected wavebands.



**Fig. 3** Some samples in the bread NIR dataset

Through the spectral unmixing, the main components of bread can be separated, so that the water spectral properties are extracted before the measurement. In the unmixing process, the multiplicative updates using Euclidean distance by Lee. D.D. [6] is used for optimal value searching. This process is demonstrated in Fig.4.



**Fig.4** The results by unmixing the spectral image of bread assuming 5 different kinds components for (a), 4 for (b), 3 for (c) and 2 for (d).

Some computing results are listed in Table 1. From Table 1, it can be seen that the values of WCI are stable during changing the number of iteration of NMF. The experimental platform is Matlab® with Intel® i5 with 4G memory. The time cost on all these process on this dataset is less than 2 minutes

**Table 1** Some water content index for the bread dataset

No.	WCI			
	Iteration (300)	Iteration (500)	Iteration (700)	Iteration (1000)
1	10.4912	10.4311	10.4212	10.4271
2	9.6609	9.6735	9.5547	9.6003
3	9.6504	9.6547	9.7100	9.6630
4	9.6142	9.6231	9.6283	9.6110

#### 4. Conclusion

Water content measurement plays an essential role in food technology and it is subject to a fast growing interest due to increasing requirements in product quality control. The loss-in-weight techniques though simple and direct, are time consuming and destructive. In this paper, the NIR spectral imaging technique was used to effectively measure the water content of the bread slice. The experimental results show the performance of the proposed method based on NMF for measuring the water content of bread.

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